

# GLAS Laser Status

GLAS Science Team Meeting

10-14-04

GLAS Instrument Science Team  
& GARB

*Contact:*

*[James.Abshire@gsfc.nasa.gov](mailto:James.Abshire@gsfc.nasa.gov)*

*301-614-6081*

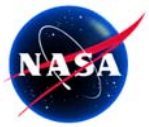




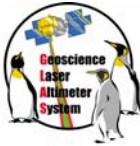
# Outline



- Laser 3 summary of pre-turn on recommendations & expectations
- Laser 3A performance to date
- Comments on Laser 3 performance & 532 nm anomaly
- GARB L3 temperature recommendations of 10-8-04 and 10-13-04
- GARB Recommended L3 temperature change decision tree
- ETU Laser - update on Extended Vacuum Test - Haris Riris
- GARB Photo-darkening hypothesis & rationale - 8-20-04
- Appendix
  - Plots of GLAS Laser energies & doubler cycling histories
  - Some ongoing discussion on possible causes for 532 nm issues with L3
  - 5-04 GARB2 briefing to Code Y AA (excerpts)



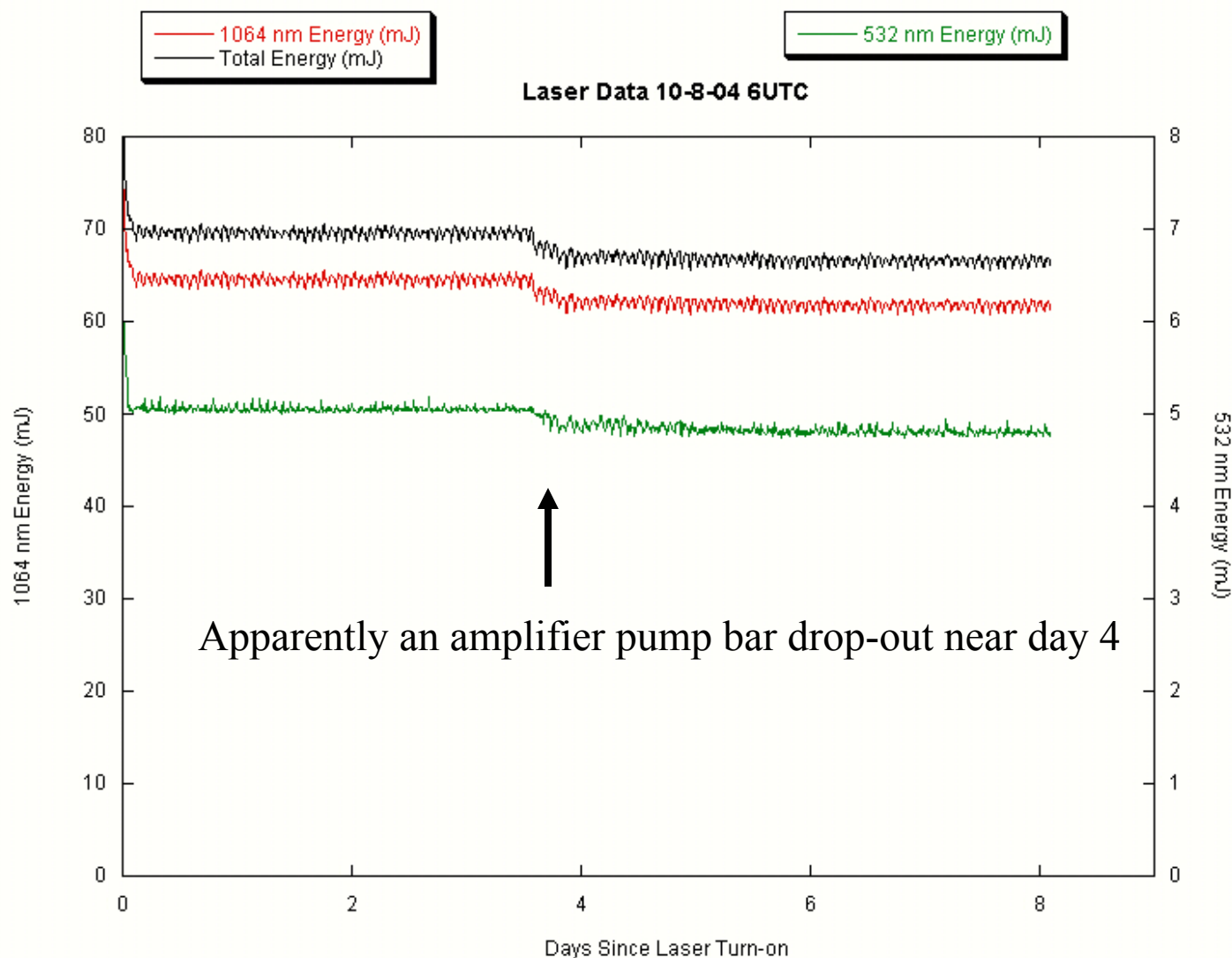
# Laser 3 Background - turn on & temperature



- Previously planned Laser 3A Laser reference (box) temperature was 16C
- GLAS commands do not set it directly - instead they set the control point of laser heat pipe controller
- Used the same setting for L3 as for Laser 2C, which operated at 16C
- However, on power on, Laser 3 settled to 13.8C
- Likely cause is better than expected thermal resistance (ie smaller thermal drops) in heat pipe system
- L3 Performance is shown in next several slides

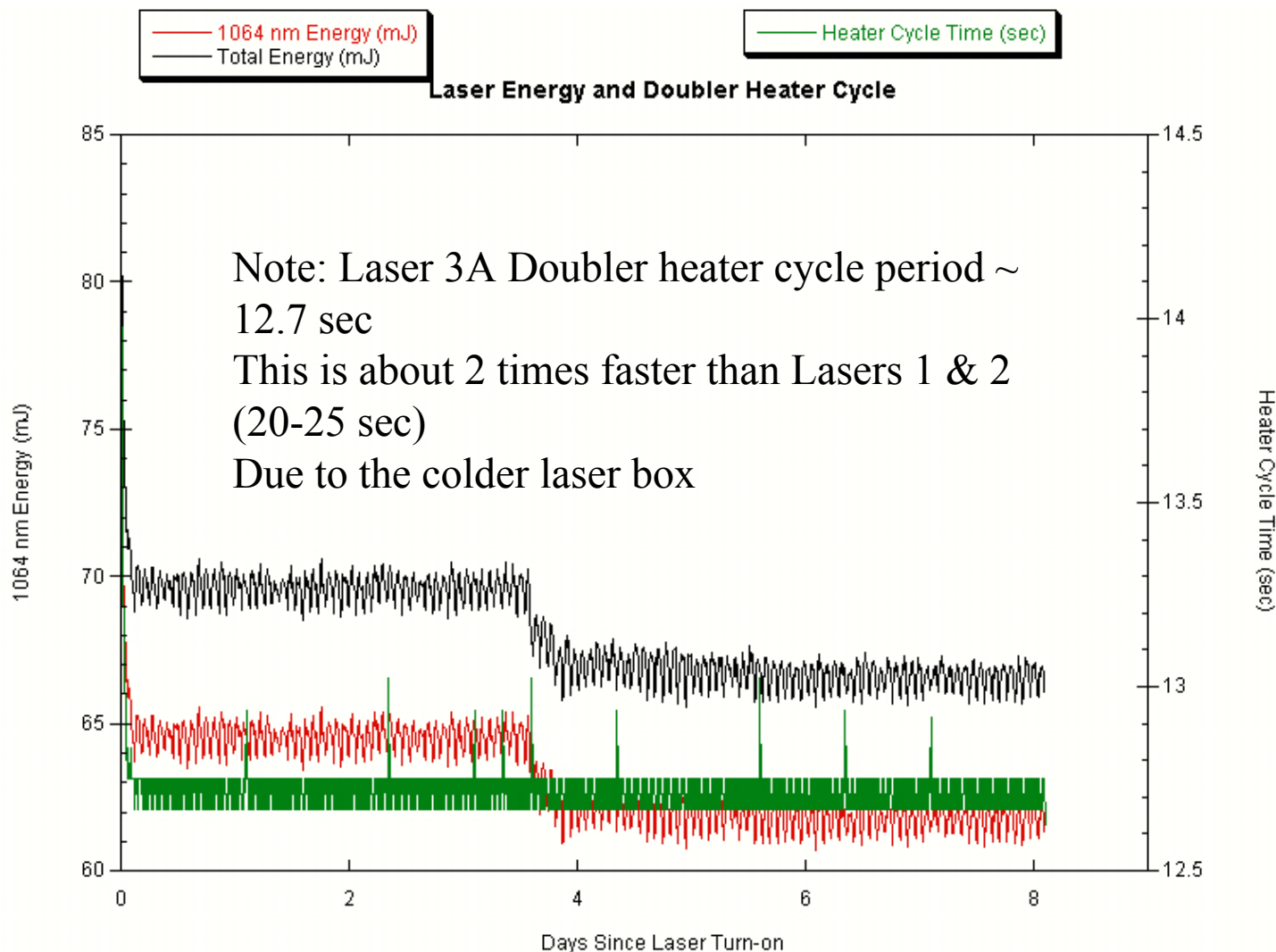


# Laser 3A Energy History through Day 8

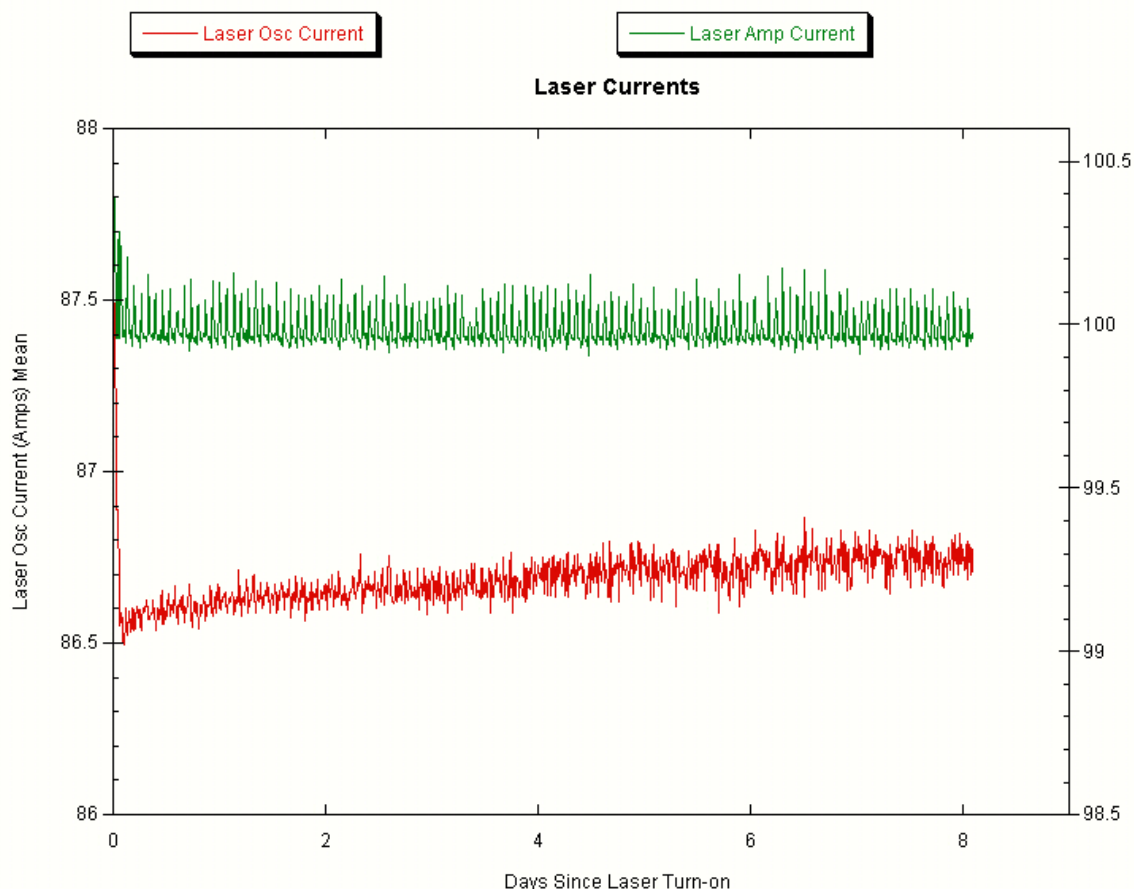




# Laser 3A Energy & Doubler Heater Cycle History



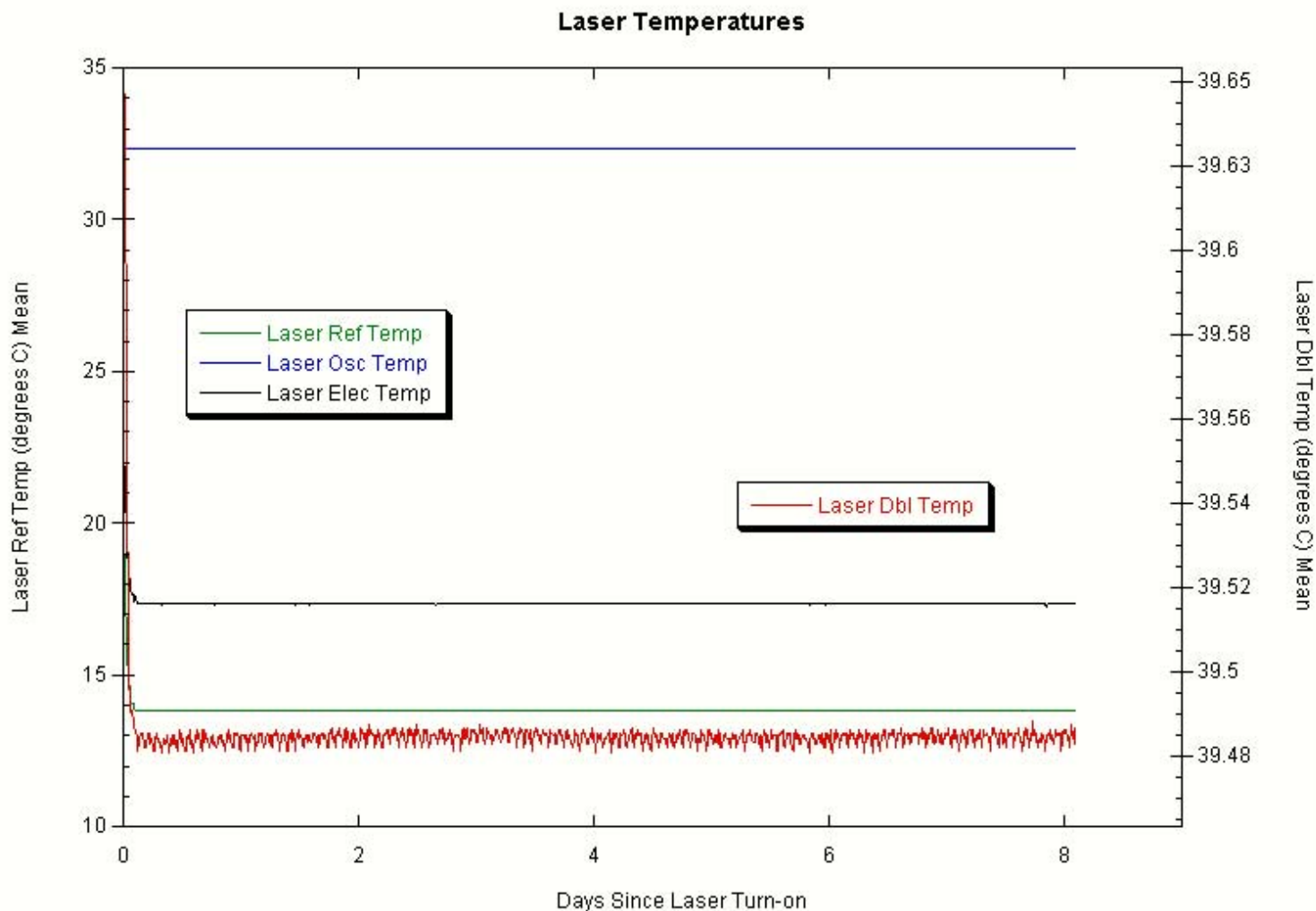
# Laser 3 Currents from 10-12-04



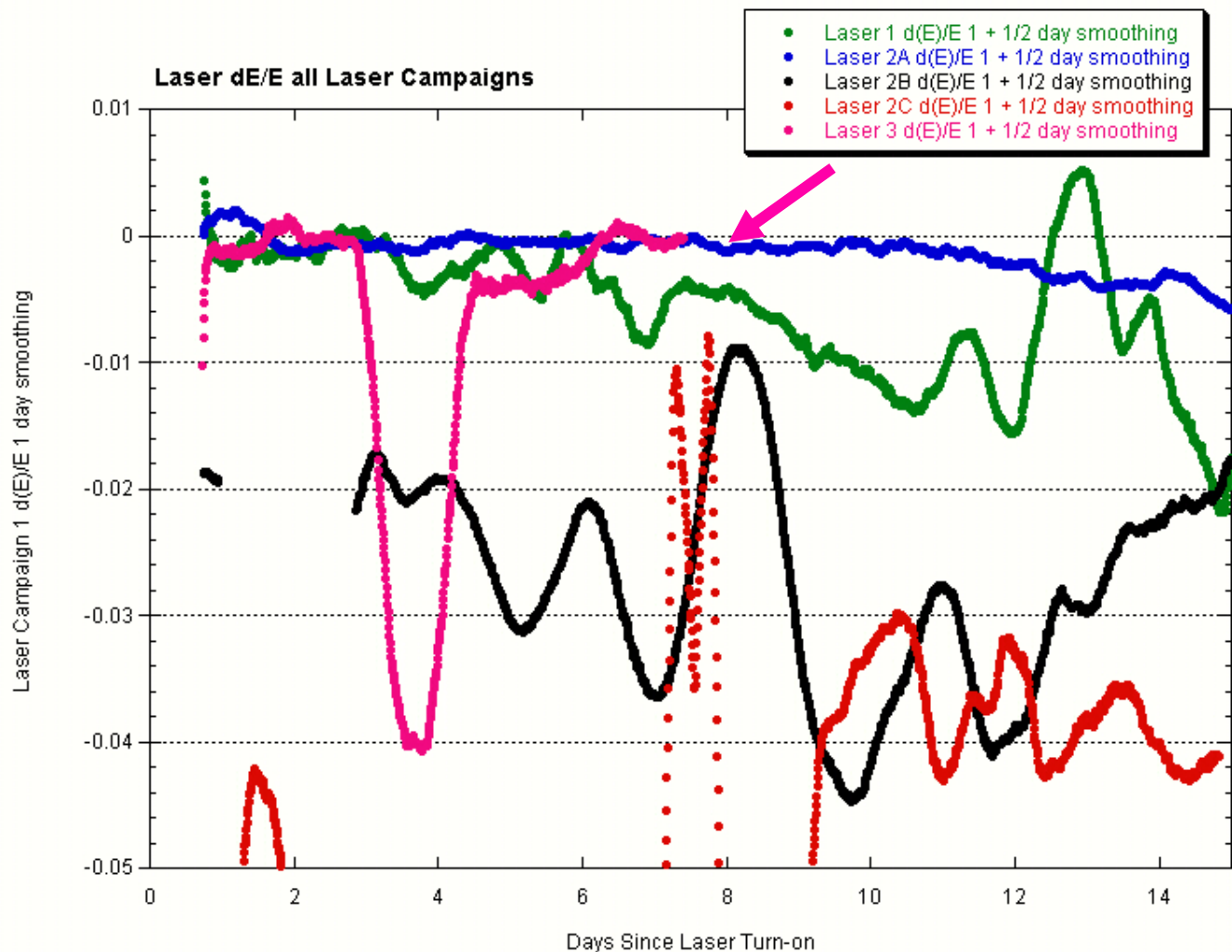
- Oscillator current has been rising slightly
- Do not know why L3 shows this and other lasers didn't
- Could be colder temp of L3
- Osc current rate of increase was 0.02A/day and has been slowing.
- If flattening trend continues, it should not impact L3 lifetime



# Laser 3A Temperatures



# Laser 3A Energy Rates compared with early L1, 2A, 2B & 2C



• Note that, with the exception of the bar drop out time, the L3 energy loss rate trend (in pink) is about the same as L2A was at this point in its history

• That is < 0.2% energy loss/day.

• L2A did not start losing energy until ~Day 11 & loss was apparent by Day 14

• The next week should be interesting.



# Comments on Laser 3 Performance



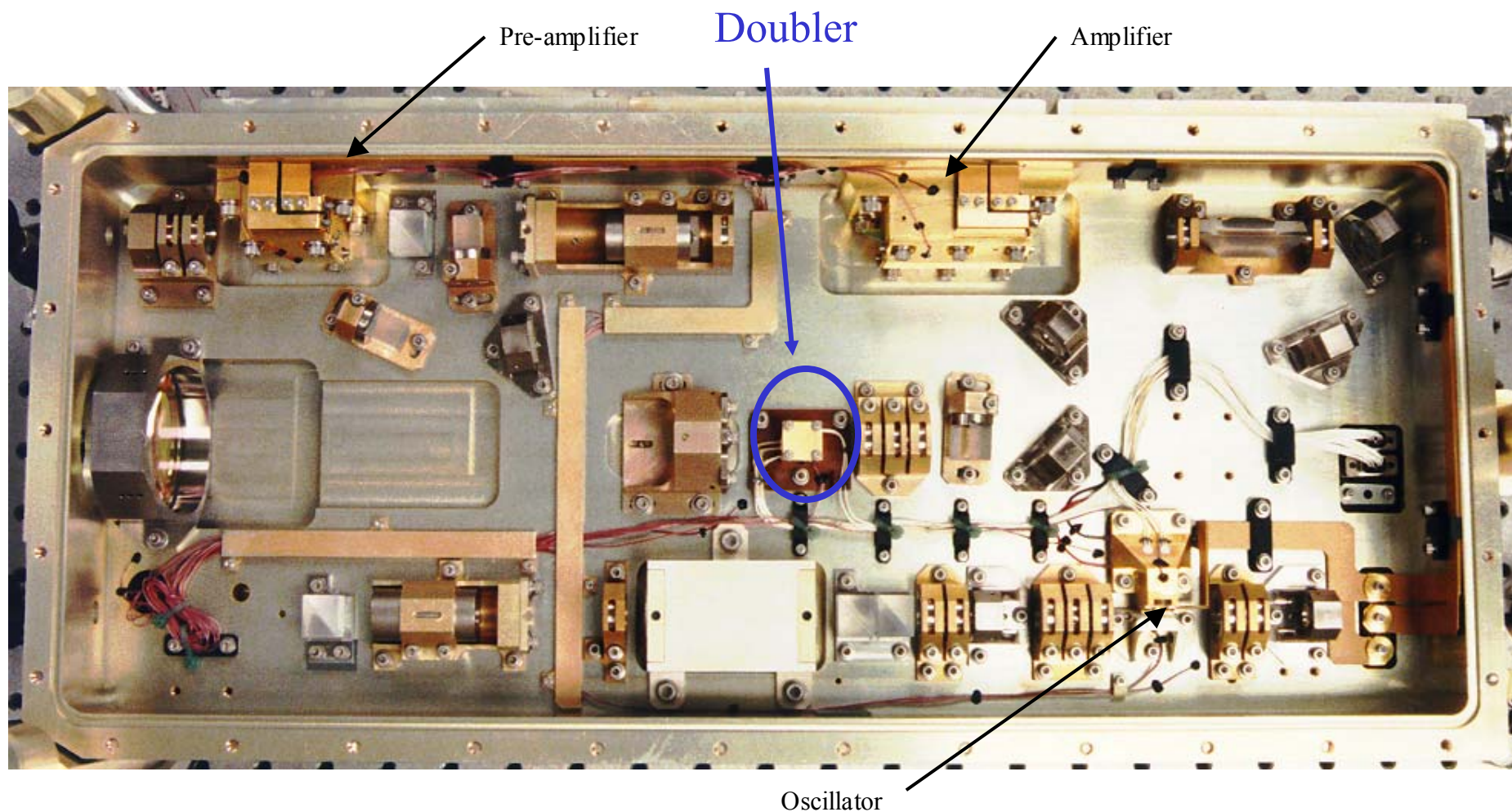
- Laser 3 has been working OK so far at 13.8C, but it has 532 nm issues
  - Energy 25-30% of expected value
  - Poor 532 nm beam quality
- Have not seen this before in flight or in the SLTC laser vacuum tests
- There has been mentioned a report of L3 in instrument level TVAC (ie laser pressurized) losing 532 nm energy. However 532 nm energy “returned” when instrument back in air
  - Since this is not a flight like condition (ie a pressurized laser box), this aspect of L3 was likely given a lower priority than the many other issues (particularly boresight) at the time.
  - Need to look back at the pre-launch reports and measurements

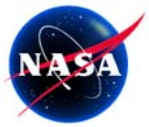


# Comments on 532 nm issue at 13.8C

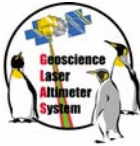


- Not sure why this is happening
- Discussions have been on some sort of doubler crystal “detuning”
  - Could be caused by a mechanical shift, a thermal gradient, or a mechanical stress change in doubler crystal or its mount
  - Or some combination of these
- Have had email & discussions within GARB and science team representatives (Zwally, Schutz, Hancock, Spinhirne) on risks to L3 operating as is
  - Is a new anomaly, and L3 is operating colder than our previous experience
  - Both these can introduce new unknown risks
- GARB recommended raising temp back to planned 16C on 10-8-04
- Zwally et al chose to counter this recommendation
- GARB met again at the science group’s request on 10-12-04, discussed again, and jointly developed a plan for a temp raise experiment, with a decision tree on the subsequent L3 temp based on the results seen





# GARB 10-8-04 Recommendation on L3 Temp



Subject: GARB3 10/8 Meeting Summary and Recommendations

Date: Friday 08 October 2004 03:24 pm

From: Carolyn Krebs <Carolyn.A.Krebs@nasa.gov>

To: jay.Zwally@gsfc.nasa.gov, jabshire@pop900.gsfc.nasa.gov, Mitchell ...

GARB3 Meeting Summary and Recommendations>

10/8/04

1. The GARB3 met in extended session to consider the green anomaly on Laser 3 and to consider a request to raise the reference temperature to 16 degrees C in an attempt to provide some mitigation.

As background, the GARB2 had recommended a Laser 3 temperature of 16 degrees C, limited by the survival heaters' trigger point.

At turn-on, the laser actually settled at 13.8 degrees C. On inquiry by the ops team, the GARB2 confirmed that it was satisfactory to leave it there, as the original desire had been to be colder than 16 degrees if not limited by the heaters.

Subsequently, it was observed that the green conversion is very low and the green beam quality extremely poor. Moreover, the green quality on the CRS is poor, making pointing reference difficult.

2. A large number of considerations were presented at the meeting, with the overriding goal to preserve laser life while trying to improve performance, both for the primary IR channel reference but also the green science channel, if possible.



# GARB Recommendation on L3 Temp (cont'd)



It was agreed by the GARB3 that the risk of increasing the temperature by 2.2 degrees C to 16 degrees C is not high and is acceptable. It was also acknowledged that the probability of improving performance significantly is not high, but it is possible that some gains may be seen.

The primary risk lies in increasing the number of green photons, which is believed to be an initiator of the contamination degradation observed on Lasers 1 and 2. However, the increased green is expected to be much less than that originally anticipated at the formerly-recommended, same 16 degrees C, as well as less than Laser 2, which ran at much higher temperatures for two of three campaigns. Despite the excess degradation on Laser 2, it successfully completed all three campaigns.

In addition, 13.8 degrees C for this laser is uncomfortably close to margins, both in laser operation and in doubler heater control. In fact, the GARB3 believes that the heater data may not be accurately reflecting on orbit conditions at this low temperature, which loses an unexpected, but critical monitor used by the GARBs 1 and 2 to assess contamination and other effects.

In addition, there is little test data at 13.8 degrees C. At 16 degrees C, we now have the Laser 2C campaign performance as a metric of expected behavior.

3. Ops Recommendation: The GARB3 recommends that the Laser 3 reference temperature be raised to 16 degrees C (~ 2.2. degrees above>current conditions) at a nominal rate of 3 degrees per day.

The GARB3 further recommends that the ops team target Tuesday, October 12 to commence the change, providing additional time to fully baseline current behavior.

Carolyn Krebs



# GARB 10-13-04 L3 Temperature Change Decision Tree

To: Carolyn.A.Krebs@gsfc.nasa.gov, John.Canham@gsfc.nasa.gov, ...  
Cc: Jay Zwally <zwally@icesat2.gsfc.nasa.gov>, Bob E Schutz <schutz@csr.utexas.edu>, ...  
Subject: GARB2 - Laser 3 Temperature change decision Tree (draft)  
From: Jim Abshire <jabshire@comcast.net>  
Date: Wed, 13 Oct 2004 08:41:57 -0400

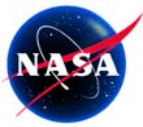
All,

Please find below a draft version of our decision tree from yesterday's GARB meeting with Jay, Bob Schutz (via telecon), Jim Spinhirne and Ed Chang. Also please note that I have added a new (suggested) criteria #3d below. 3d. addresses the possibility that at 16C the L3 doubler starts to recover from its anomalous state and makes > 6.6 mJ energy with a good beam quality. I feel if this occurs, then we (GARB and science team leaders) should discuss this issue again.

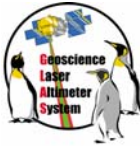
The rationale for the 3d suggestion is that, if this occurs, then L3 is leaving its present "unexplored territory with the doubler" and returning to our GLAS laser experience base. As John Canham pointed out yesterday afternoon, when the doubler is operating in its anomaly region (ie like now), we do not understand it. Therefore cannot predict its consequences and cannot rule out the doubler having a worse effect on laser 3 lifetime than when it works normally. Obviously this means it is riskier to operate the doubler this way than operate it normally. Also note that my suggested action for 3d. is not to stay there, but to discuss it further.

I also feel that, given the unknown lifetime risk from doubler anomaly, there is less risk to L3 lifetime in executing this plan sooner as compared to later.

Jim



# GARB 10-13-04 L3 Temperature (Cont'd)



## Laser 3 Temperature Change Plan and Decision Tree (DRAFT)

As agreed to in 10-12-04 GARB meeting with mission science representatives

1. Raise the reference temperature of Laser 3 from 13.8 to 16C at a rate of  $\sim 1\text{C}/8$  hours.
2. Wait a day\* for the laser performance to stabilize and to analyze the laser-related telemetry  
(\* a question - is a day long enough ? - it probably isn't - I suggest 2 days instead)
3. Subsequently, keep or adjust the laser reference temperature setting of Laser 3 according to the following criteria:
  - a. If there is an improved 532 nm beam quality, and the 532 nm Energy reading is  $< 6.6$  mJ (ie less than the upper bound):  
Action: keep reference temp at 16C.
  - b. If there is only the expected incremental improvement in 532 nm energy, but not a significant improvement in 532 nm beam quality:  
Action: return laser reference temp to 13.8 C.
  - c. If the 532 nm Energy reading is  $> 6.6$  mJ, but the beam quality is not improved:  
Action: return laser reference temp to 13.8C.
  - d. (Suggested) If the 532 nm energy reading is  $> 6.6$  mJ, and the 532 nm beam quality is improved:  
Action: discuss it (or drop Laser temp  $\sim 1\text{C}$  to reduce energy)
4. If the laser reference temperature is lowered again, change at the  $1\text{C}/8$  hour rate.
5. Note we need to define the criteria used to assess 532 nm beam quality. Is it the energy in the CRS spot, a 532 nm LBSM scan, or both ? I advocate both.



# GARB 10-13-04 Recommendation on L3 Temp



Date: Wed, 13 Oct 2004 09:18:44 -0400

From: [Carolyn Krebs <Carolyn.A.Krebs@nasa.gov>](mailto:Carolyn.Krebs@nasa.gov)

To: [jay.Zwally@gsfc.nasa.gov](mailto:jay.Zwally@gsfc.nasa.gov), [jabshire@pop900.gsfc.nasa.gov](mailto:jabshire@pop900.gsfc.nasa.gov), [Mitchell Davis <Mitchell.L.Davis@nasa.gov>](mailto:Mitchell.L.Davis@nasa.gov), ...

**Subject:** GARB3 10/12 Meeting Summary and Recommendations

GARB3 Meeting Summary and Recommendations 10/12/04

1. The GARB3 met with the science representatives to reconcile the 10/8 GARB3 recommendation to increase the temperature of Laser 3 by 2.2 degrees C with the counter-position subsequently communicated by the Project and GLAS scientists. Pros and cons were re-reviewed.

A strawman scenario that provided the scientists with options, should the temperature increase be approved, was generated and evolved into a decision tree. The decision tree allows for a return to lower temperature if no improvement is seen in beam quality or if the beam quality improves but with significant green energy that could trigger excessive degradation. The dwell time at temperature for the GARB3 to assess effects is sufficiently short that possible exposure to higher green during that time should not have a large adverse effect. The final decision on a temperature increase, and the timing thereof, is the prerogative of the science team.

2. Ops Recommendations: The GARB3 recommendation to increase the temperature by 2.2 degrees C at 3 degrees C per day remains, as modified to allow for return to 13.8 degrees C. The GARB3 also requests that data dumps be as frequent as possible to them during the change and dwell (TBD time - to be clarified) in order to provide timely ops recommendations. -- It was agreed by the GARB3 that the risk of increasing the temperature by 2.2 degrees C to 16 degrees C is not high and is acceptable. It was also acknowledged that the probability of improving performance significantly is not high, but it is possible that some gains may be seen.



# GLAS ETU Laser Extended Vacuum Operation & Performance Characterization

Haris Riris

10-12-04

- Objectives:
  - Expose GLAS ETU laser to continuous operation in vacuum
  - Monitor, archive, and trend most important laser parameters
  - After vacuum ops, perform “autopsy” on laser to better understand effects of vacuum
  - Improve understanding of GLAS “faster than predicted” laser energy decline
  - Apply knowledge gained to future NASA space laser programs



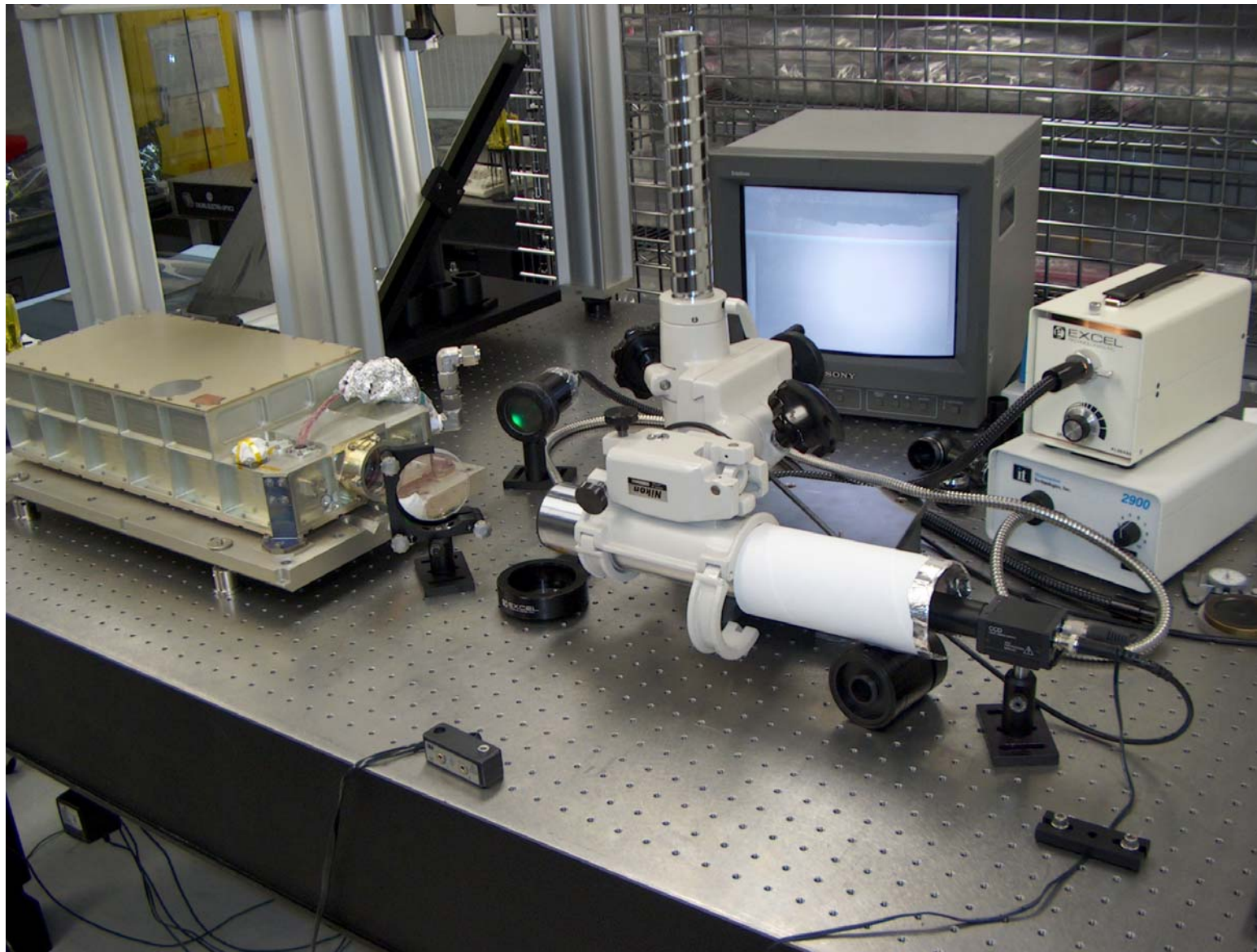
# ETU Laser Extended Vacuum Test History



- An extended vacuum test of ETU laser (the pre-flight unit) should provide much better insight into cause of the flight lasers power decline
- History:
  - Plan developed late spring 2003 & recommended by IGARB
  - Proposed to Code Y for support summer 2003
  - Support received from ESMO & Code Y January 2004
  - Laser lab (B33/H017) & TVAC chamber setup from equipment moved from SLTC
  - ETU Laser and test setup prepared in Laser lab
  - Performed a visual inspection (from outside the box) of the doubler crystal
  - Completed pre-test performance characterization of ETU Laser
  - Recovered from vacuum leaks, vacuum pump failures, and coolant leaks
  - ETU vacuum bake (complete flight vac. processing) ready to start week of 10-11-04
  - Extended vacuum test starts after that

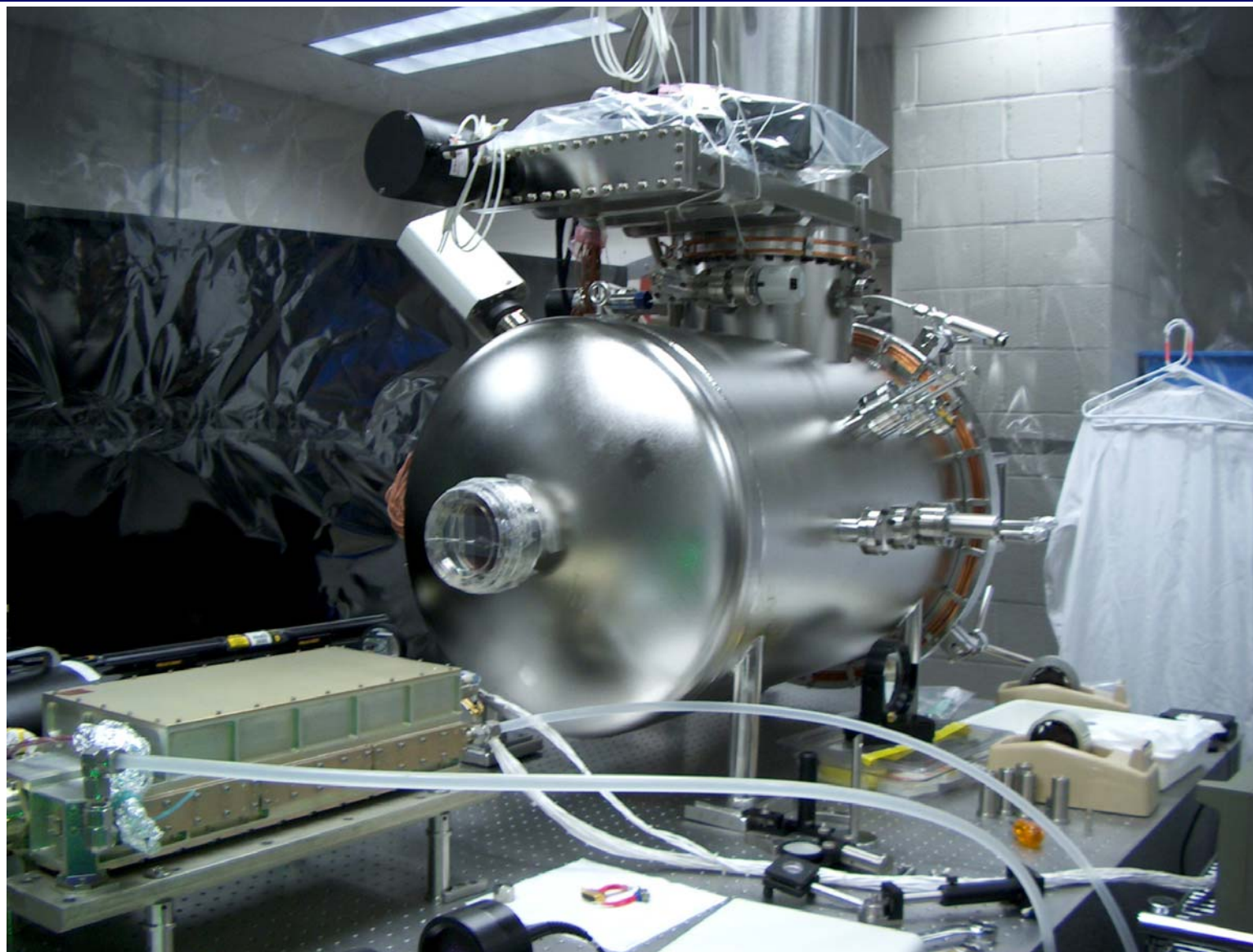


# Setup for Imaging ETU Laser Doubler Surfaces



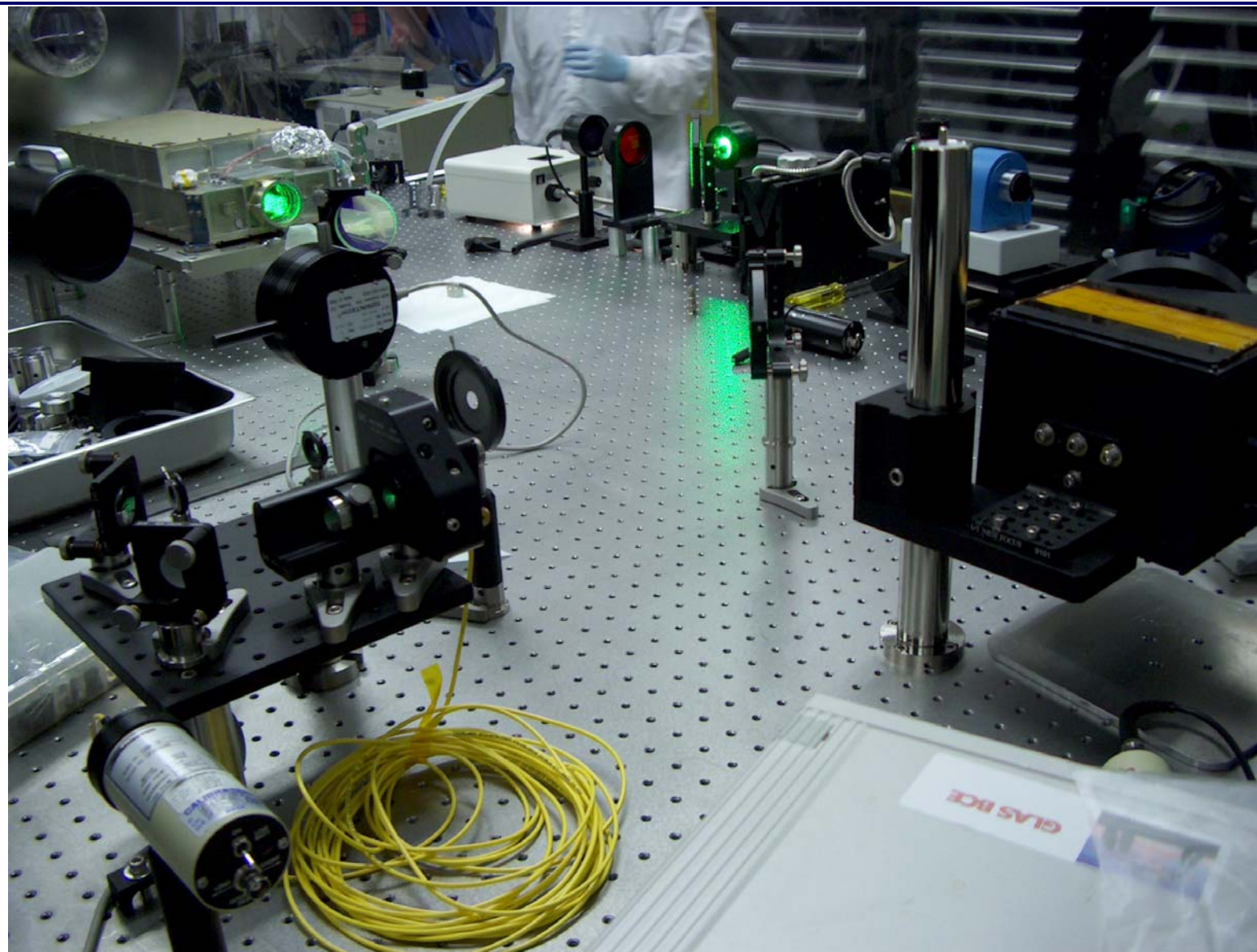


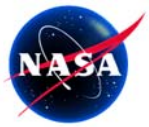
# Vacuum Chamber Setup in B33/H017 - 6/30/04



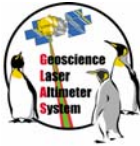


# Pre-Test Characterization of ETU Laser- 6/30/04





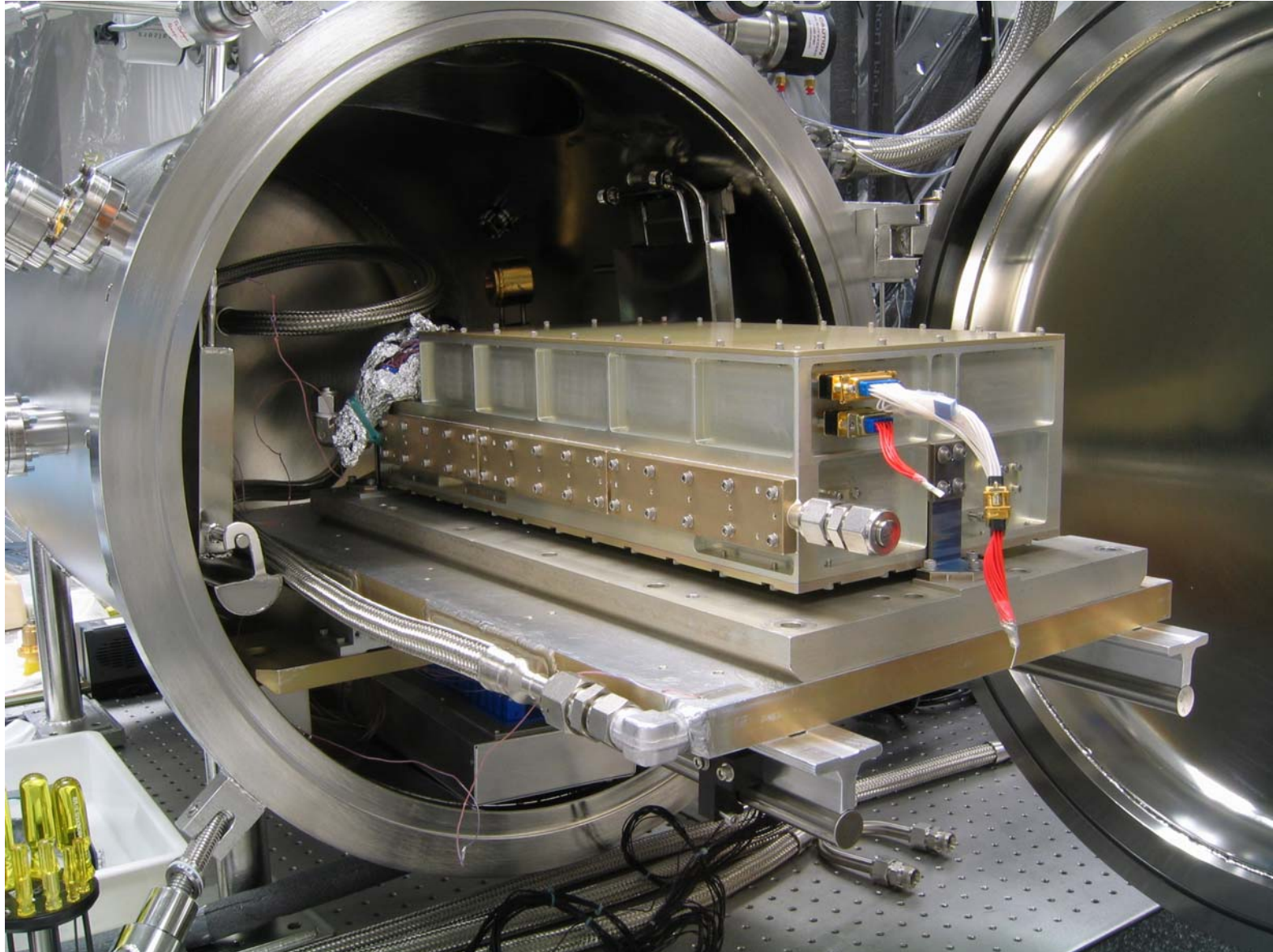
# Setup & Test Approach

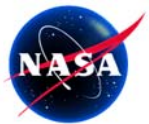


- (Lids on) inspect ETU laser prior to vacuum operation
- Operate laser in air-air for limited time to measure current energy levels & get baseline
- Set up chamber in B33 lab (H017) and qualify chamber and facilities
- Set-up and maintain a “clean area” around chamber
- Setup fail-safe mechanisms for laser & chamber, power but not for data acquisition
- Use existing SLTC and GLAS BCE equipment and software whenever possible
- Acquire 40 Hz energy data (whenever possible)
- Operate 24/7 unattended (16 hrs/day & weekends) after initial setup
- Anticipate vacuum test duration 4-6 weeks
- Detailed Inspect/analysis (post-mortem) of the laser optics after the test.

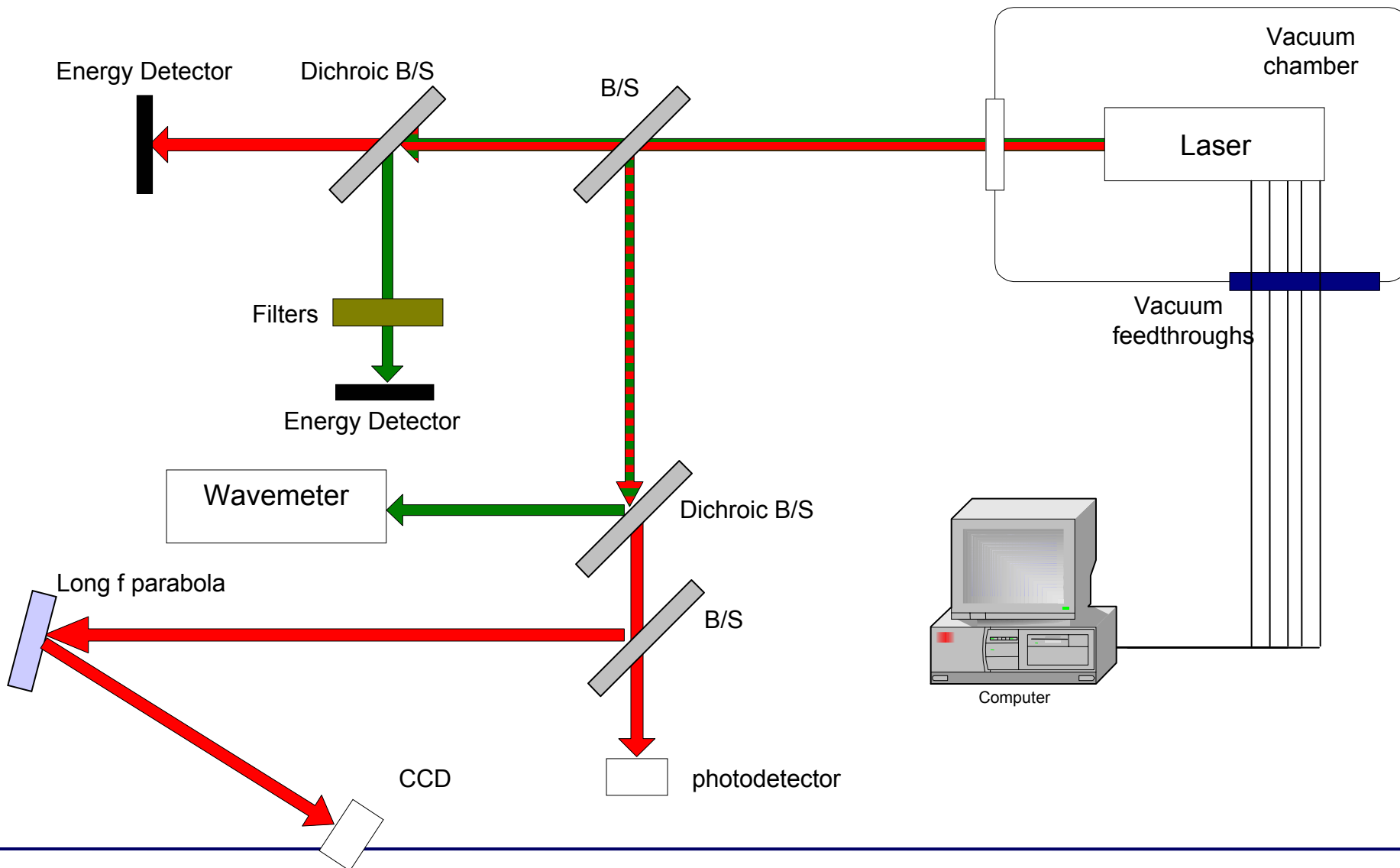


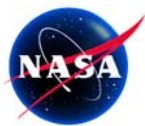
# GLAS ETU Laser being inserted into Vacuum Chamber



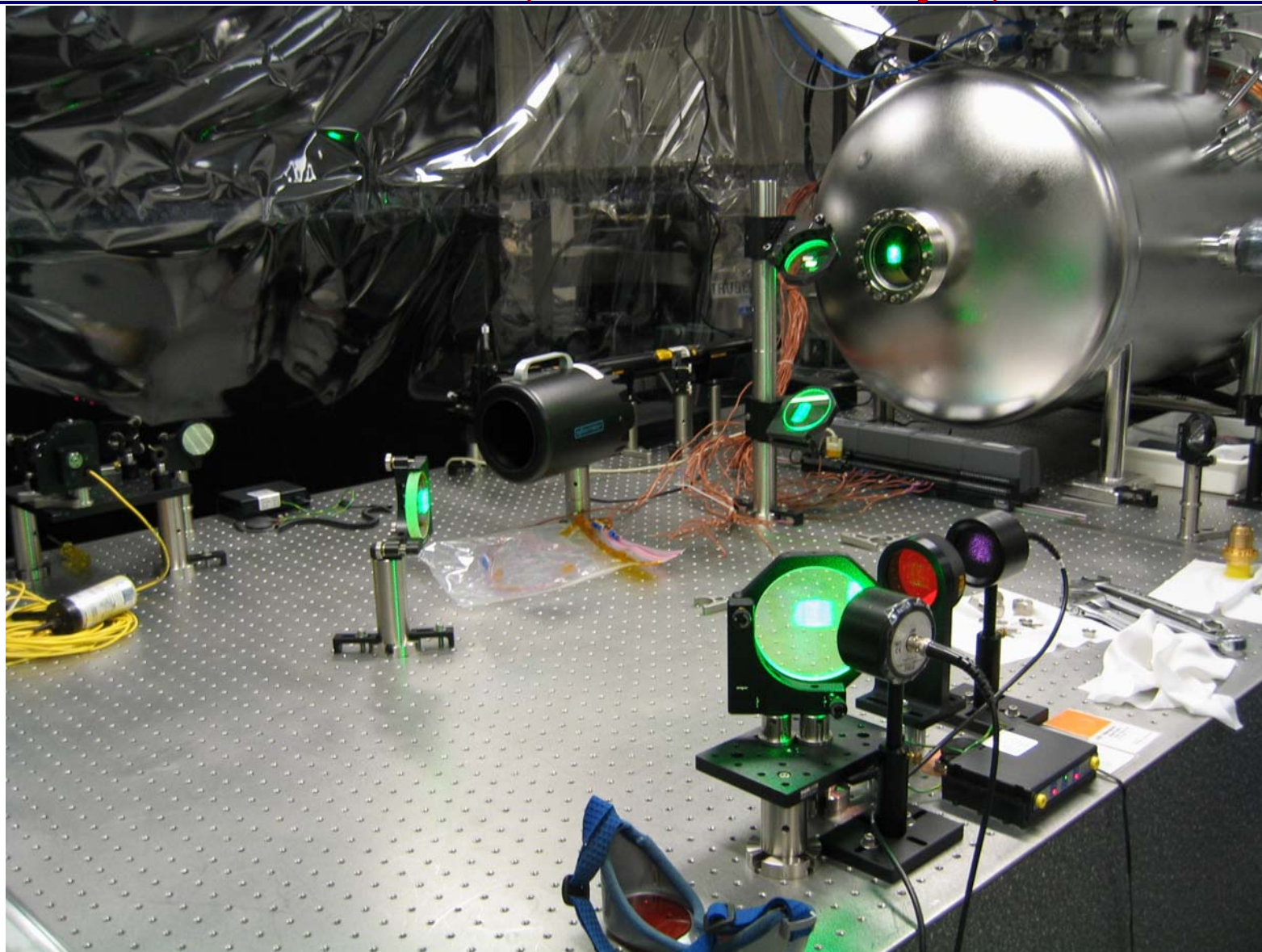


# ETU Laser - Extended Vacuum Test - Optical Setup





# GLAS ETU Laser in Vacuum Chamber (not at vacuum yet)





# Original Schedule



ID	Task Name	Start Date	End Date	Duration	2004				
					June	July	August	September	October
1	Power Setup	6/1/2004	6/22/2004	16d					
2	Wall penetrations and modifications	6/1/2004	6/22/2004	16d					
3	Pulmbing installation	6/1/2004	6/18/2004	14d					
4	Chamber Qualification (cleaning certification etc)	6/23/2004	8/4/2004	31d					
5	Clean tent installation and certification	6/17/2004	7/23/2004	27d					
6	Misc facilities (LN2, Safety cert. etc.)	7/1/2004	7/15/2004	11d					
7	Harnessing	6/12/2004	7/14/2004	23d					
8	Software set upwith simulated signals	6/7/2004	6/25/2004	15d					
9	Software tests with HW but w/oETU laser	6/28/2004	7/26/2004	21d					
10	Software Tests with ETU laser	7/27/2004	8/3/2004	6d					
11	Optical Test Setup	6/7/2004	6/17/2004	9d					
12	Optical Test Checkoutw/o ETU laser	6/17/2004	7/2/2004	12d					
13	Optical Test Checkoutwith ETU laser	7/16/2004	8/4/2004	14d					
14	Baseline ETU in Air	8/5/2004	8/6/2004	2d					
15	Vacuum Test	8/9/2004	10/8/2004	45d					

Note: Start date was impacted by a chamber leak, a vacuum pump failure, coolant line leaks, and TQCM failure

Have overcome all problems

Test to start week of 10-11-04



## Status as of 10-13-04



Date: Wed, 13 Oct 2004 15:04:38 -0400

To: Carolyn Krebs <Carolyn.A.Krebs@nasa.gov>, jay.Zwally@gsfc.nasa.gov ...

From: Haris Riris <hriris@pop900.gsfc.nasa.gov>

Subject: Update on ETU Test

All

A quick update on the ETU test:

We have received our final approval from Laser Safety and we will commence laser firing tomorrow. The test will run for approximately 2 months unless the GARB2 recommends otherwise.

Thanks

Haris Riris, PhD

Code 924 Building 33 Room D426

NASA Goddard Space Flight Center

Greenbelt, MD 20771



# GLAS Lasers 1&2 - Gradual Energy decline hypothesis & Laser 3 turn-on proposal



GARB2 - 8/20/04

## *A. Hypothesis:*

Laser 1 & 2 knee and gradual energy decline curves are caused by:

1. A gradual low level out-gassing from the adhesives used in the laser cavity
2. The concentration is sufficiently small &/or the reaction rate is sufficiently low at 1064 nm that it is not a problem for oscillator
3. However the higher energy photons, either at 532 nm, 266 nm (or both), produced in the doubler cause a much higher reaction rate and they gradually cause photo-darkening of a few surfaces in laser
4. Primary darkening sites are exit face of doubler & negative group of final beam expander.
5. The 3M 2216 adhesive (used as staking compound) seems the most likely suspect

Used in ~200 exposed places in cavity

Canham's new thermal extraction tests shows it out-gases toluene at low rates

6. Evidence also showed "bar dropout" (effluents ?) increased rate of doubler heating near end of L2A
7. Cannot exclude Nusil and stycast as a possible sources of effluents (at low rates)



## B. Rationale & comments - 1 of 2



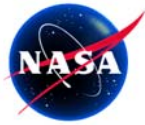
1. No observable effect on 1064 nm of oscillator is consistent with the GLAS laser processing following the prior (& successful) approaches of lasers for MOLA, NEAR, Clementine, etc.
2. The ~10 day delay before onset of L2 doubler heating may be due to :
  - a. protection of residual WV on laser, which takes a while to be scrubbed off
  - b. or the photo-darkening process takes a while to start
3. The initial rate of doubler heating during L2A was slower ( $\sim 1/2$ ) of L1.

Could be due to (either or both):

  - L2 in space 6 months vs 1 month for L1 (more time for outgassing)
  - L2 was started at 26C vs  $\sim 30$ C for L1 (lower rates of sustained emission)
4. Energy loss rate (%/day) was  $\sim$  constant during each campaign, except for special events

Growth of attenuating layer was at constant rate (ie Beers law) during each campaign

Energy loss rate (% loss/day) successively higher for each campaign
5. No additional loss between campaign(when laser off) -> loss mechanism requires laser photons
6. LPA data and the 11/03 ground observations of 532 nm (“green spot chase photos”) seem consistent with a  $\sim$  uniformly applied fine grain or haze pattern applied to laser optics at or after the doubler
7. Temp spike near day 18 of L2A seems to point to it driving effluent from the laser box
8. Based on other findings this seems likely to be an adhesive



## B. Rationale & comments - 2 of 2



9. Bar drop out at day 53, near end of L2A, caused immediate increased rate of photodarkening

Seems that constituents released by the bar dropout event increased the rate of loss

10. Recent Canham thermal extraction tests, using a cryo-trap show & GCM, show toluene & zylene effluent (at very low levels) from heated Scotchweld & Stycast

11. Toluene previously known to lower damage threshold in laser cavities without oxygen present

12. VUV photolithography papers (at 197 & 154 nm) point to photo-darkening of trace hydrocarbon contaminants being an issue (and forming “haze”-type carbon films on optics)

13. Calculations by Rob Afzal indicate that UV photons (at 266 nm) can be produced by doubler at low (nJ) energy levels. Note at 266 nm, there are  $2.7 \text{ E}9$  photons/nJ.

14. Darkening continued even after doubler was heated to point it quit converting 532 nm photons

15. Once photo-darkening gets established, it may not require 532/266 nm photons to continue

It seems plausible that this is a multi-stage process (one which changes phases with time)

16 . It seems plausible that a thin dark film, being heated by mJ of absorbed laser energy will get hot

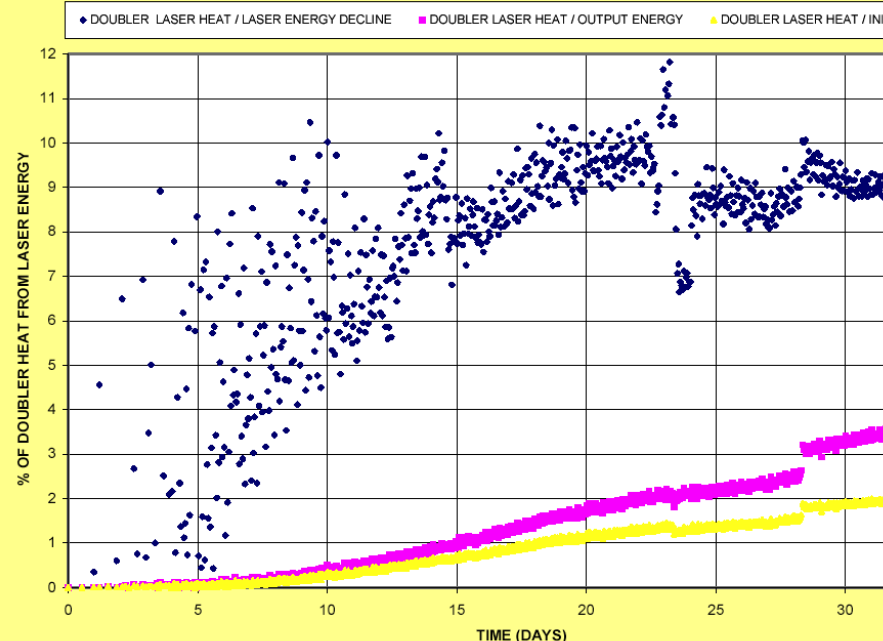
- Seems plausible that during later phases that a hot thin film in contact with trace hydrocarbons or silicone molecules might continue to thermally drive further darkening/carbonization
- Once the film gets hot enough, 532/266 nm light may not be required for continued darkening & attenuation



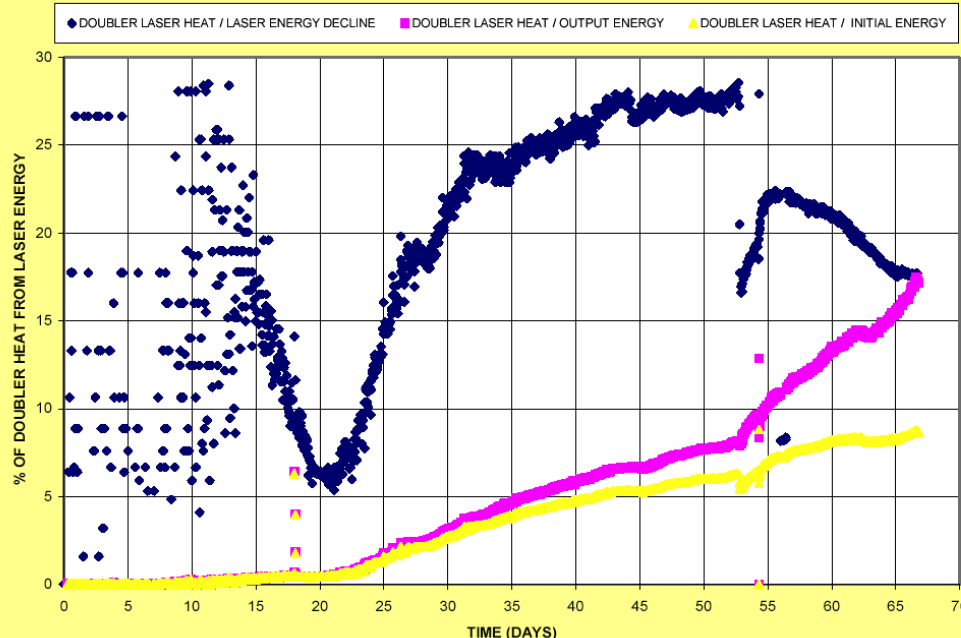
# Some Laser doubler heating history plots - 1 of 2



LASER 1 DOUBLER ABSORBED ENERGY PERCENTAGES



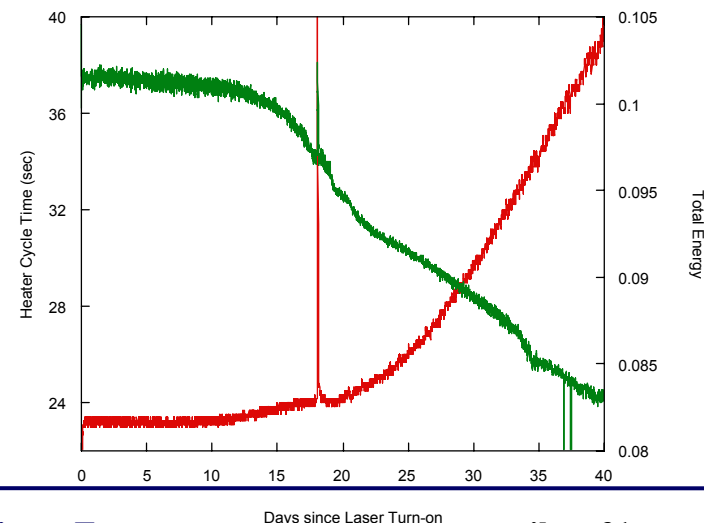
LASER 2 DOUBLER ABSORBED ENERGY PERCENTAGES

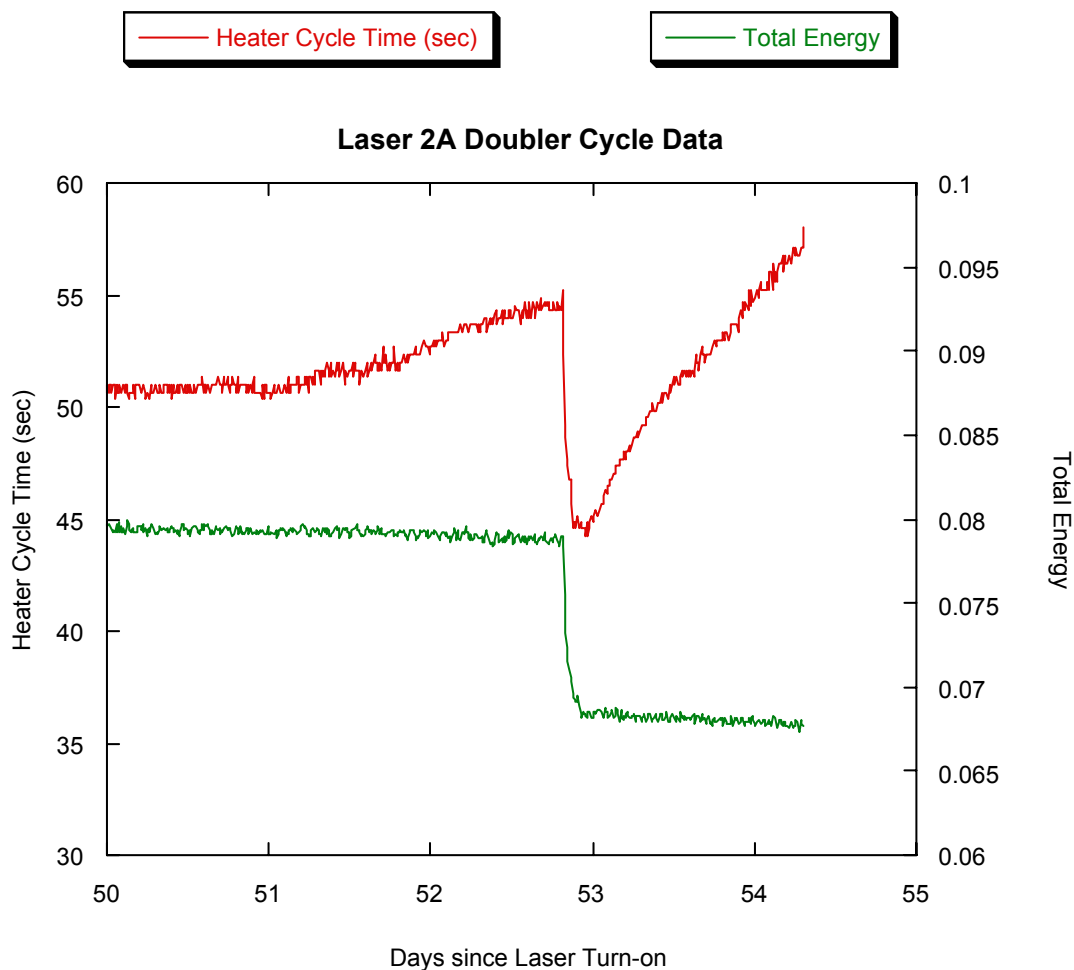


- Laser 1 in space ~ 1 month before turn on
- L1 operated at ~ 30C
- L1 doubler heating started almost immediately after laser turn on
- L1 doubler heating rate (% from laser energy) =  $1\%/18 \text{ days} = 0.055\%/day$

- Laser 2 in space ~ 6 months before turn on
- Laser 2 operated at ~ 26C
- Laser 2A heating rate undetectable before day 11
- L2A doubler heating rate ~ 0.028%/day before temp spike, ~ 1/2 rate of L1
- Laser 2A rate increased dramatically ~ 2 days after temp spike

Laser 2A Doubler Cycle Data





- Doubler heating rate increases immediately following L2A bar drop event
- Indicates that the bar drop stimulated an increased rate of doubler heating
- Possibly via materials emission from bar ?



# Laser 3 turn-on recommendation 1 of 2



## *C. Laser 3 recommendation:*

Start & run laser 3 at its coldest practical temp (~16 C)

## *D. Rationale:*

1. Out-gassing rates of all adhesives are temp activated: colder -> lower out-gassing rates
2. Colder temps also reduce the energy (# of photons) of 1064, 532 (& residual 266 nm) in laser
3. Both lower level of contaminants & fewer 532/266 nm photons -> slower rate of photo-darkening
4. L2A showed that either longer waiting time or 26C (or both) was better than 30C

Note that the in-space waiting time for Laser 3 will be 18 months.

5. Colder also reduces the current drive amplitude to the osc pump diode
6. Colder is better for normal wear-out mechanisms in diode bars (ie it lowers the current threshold)
7. L2C ops showed that operation with diode drive pulse width variations (ie in the “keepout zone”) was not not hazardous, as expected
8. Temp spike movement of L2 & L2C ops showed boresight alignment is also better for cold lasers
9. To minimize solder stresses in diode package, need Richard Dame analysis on temp transition rates



## Laser 3 turn-on recommendation 2 of 2



### *E. Other approaches for Laser 3 which were considered and rejected:*

1. Can't turn off the doubler heater - no switch
2. With small exit port in laser & lack of bakeout heater cannot effectively "bake out" the adhesives
3. Can't reduce laser ops temp below 16C due to the instrument emergency heaters
4. Risky to turn off laser emergency heater, because it would disable all emergency heaters on GLAS
5. Would have to operate laser at ~ 39C to drive doubler temp "too high" & stop 532 nm production

This hot is bad for diodes & is well outside the upper test limits of laser

Hot temps increase the out-gassing rate - constituent lifetime is long inside box

Hot lasers move beam away from boresight alignment

### *F. Other characteristics of Laser 3 (SN1) to remember:*

1. Was unit repaired after "bar blowout event" which occurred in an amplifier pump array during 11/01
2. Cannot exclude the possibility of latent damage to other diodes from blowout
3. IGARB found its SDL diode array production records show reworked diode array in amp (?)
4. Rework likely increased the extent of indium solder attack on its gold bond wires